Platform Competition and Compatibility Decisions: The Case of Apple's iPad vs. Amazon's Kindle*

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Abstract

We study the compatibility decisions of two competing platforms when they generate profits through both hardware sales and royalties from content sales. We consider a game-theoretic model in which the two platforms' hardware may offer different standalone utilities to users, and users have different preferences over the two platforms. We find that the incentives to establish one-way compatibility—the platform with greater standalone value allows users of the competing platform to access its content—can arise from the difference in their profit focuses. When the difference in the standalone utilities is sufficiently large, the platform with greater standalone value finds it optimal to generate most of its profit from hardware sales and the one with smaller standalone value prefers to make most its profits from royalties of content sales. Compatibility increases the asymmetry in the two platforms' profit focuses and leads to greater profits for both firms. Furthermore, we show that neither platforms have incentives to establish one-way compatibility the other way round, and social welfare is greater under one-way compatibility than incompatibility. We also investigate how factors such as different production costs of the platforms, exclusive content, endogenized royalty rates, and wholesale vs. agency models used by the platforms affect the platforms' compatibility incentives.

Keywords: compatibility; two-sided markets; platform competition; e-reader market

1 Introduction

An increasing number of markets today are organized around platforms, which enable consumers to access and/or purchase complementary goods and services. These platforms are two-sided because both sides—consumers and complementors—need to gain access to the same platform in order to interact or conduct transactions. For example, operating systems such as Windows, Macintosh, or Linux serve as platforms connecting two parties: on the one side, computer users need an operating system to access software applications; on the other, independent software application developers need to access the operating systems programming interface to develop software applications which they can then sell to consumers. Other examples of such markets include video game consoles, newspapers, smartphones, e-books, credit cards, shopping malls, and social networking sites. Platform-based markets comprise a large share of today's economy—Ranked by market value, 60 of the world's 100 largest corporations earn at least half of their revenue from platform-based markets (Eisenmann 2007).

The literature on platform-based markets has studied strategies a platform can use to grow its business such as two-sided pricing (e.g., Rochet and Tirole 2003; Parker and Van Alstyne 2005; Armstrong 2006; Hagiu 2006; Seamans and Zhu 2014), quality investment (e.g., Casadesus-Masanell and Llanes forthcoming; Zhu and Iansiti 2012), adopting innovative business models (e.g., Economides and Katsamakas 2006; Casadesus-Masanell and Zhu 2010), enveloping adjacent platform markets (e.g., Eisenmann et al. 2011), and managing relationships with complementors (e.g., Carrillo and Tan 2008; Hagiu and Spulber 2013; Zhu and Liu 2014).

Our work complements these studies by examining competing platform providers' compatibility decisions. The study is motivated by empirical observations in the e-reader market, where two major platforms—Apple's iPad and Amazon's Kindle—compete aggressively against each other. These hardware devices allow consumers to read e-books through their proprietary e-book readers, iBooks and Kindle Reader. Amazon's Kindle device was first released in 2007 and Apple's iPad was first released in 2010. After Apple's entry into the market, Amazon decided to make its Kindle Reader available on Apple's device, allowing consumers to read e-books purchased from Amazon on Apple's iPad. Although Apple is well known for rejecting third-party applications when they compete directly with Apple's own offerings, it approved Amazon's Kindle Reader for its hardware device. On the other hand, however, Apple has not reciprocated and made its iBooks available for Amazon's Kindle device.

What motivates the two competing platforms to establish this one-way compatibility but not vice versa? How does compatibility affect their profits and social welfare? How do factors such as different production costs and exclusive titles affect platforms' compatibility incentives? We develop a formal model to analyze this phenomenon. In our model, two competing platforms with different standalone value to users generate profits from both hardware sales and royalties from content sales. We analyze a three-stage game. In the first stage, both platforms make compatibility decisions. Compatibility is achieved when one platform decides to make its proprietary content reader available on its competitor's platform and the competitor agrees. In the second stage, platforms decide on their hardware prices. Finally, users purchase hardware and content.

We find that the incentives to establish one-way compatibility—the platform with greater standalone value allows users of the competing platform to access its content—can arise from the difference in their profit focuses. When the difference in the standalone utilities is sufficiently large, without compatibility, the platform with greater standalone value finds it optimal to generate most of its profit from hardware sales and the one with smaller standalone value prefers to make most its profits from royalties of content sales. Compatibility increases the asymmetry in the two platforms' profit focuses and leads to greater profits for both firms. Compatibility incentives can also arise when the royalty from content sales is large as in such cases, compatibility reduces incentives of platforms to compete for users and thus allows the two platforms to charge high hardware prices. Furthermore, we show that neither platforms have incentives to establish compatibility the other way round, and social welfare is greater under one-way compatibility than incompatibility.

We relate our findings to the e-reader market. In the e-reader market, as Apple's iPad provides many other features beyond reading e-books, Apple in equilibrium generates more profit from its hardware sales than royalties from e-book sales. In contrast, Amazon's Kindle is almost exclusively an e-book reader, generating most its profit from e-book sale royalties in equilibrium. When this difference in profit focuses is large enough, we find that both Apple and Amazon are willing to have Kindle Reader available on iPad. In this case, Amazon gains additional e-book sales because consumers who purchase iPad can also purchase e-books via Kindle reader, and Apple gains additional hardware sales because now consumers value iPad even more than in the case of incompatibility because of the access to Kindle reader. The additional profit Apple generates from hardware sales more than compensates its loss in royalties from e-book sales through its iBooks. Similarly, the additional profit Amazon generates from e-book sales is greater than its loss in Kindle device sales. In particular, when Amazon subsidies Kindle sales, we show that it is always in Amazon's interest to have Kindle Reader on Apple's iPad. However, it is never in either Apple or Amazon's interest to have iBooks available on Kindle device.

We also extend our baseline model to examine a variety of factors that may affect the platforms' compatibility incentives. We find that factors reducing (increasing) the asymmetry in the two platforms' profit focuses tend to reduce (increase) their incentives to become compatible. For example, when we introduce additional production cost for the platform with greater standalone value, we increase the importance of content sales to the platform. As a result, the profit focuses of the two platforms become more similar and they thus have lower incentives to be compatible. When the platform with smaller standalone value has exclusive content, on one hand, exclusive titles increases the platform's reliance on software, which increases the heterogeneity in two platform providers' profit focuses and thus increases the likelihood of compatibility. On the other, these exclusive titles increase the value of the platform to its users, thus reducing difference in the utilities users receive from both platforms. This reduction in heterogeneity reduces the likelihood of compatibility. In the end, whether exclusive titles increase the likelihood on compatibility depends on their relative impact on utility difference and extra profits from additional content sales to the platform.

1.1 Literature Review

Our model shares common features with the theoretical literature on two-sided markets (e.g., Rochet and Tirole 2003; Caillaud and Jullien 2003; Hao et al. 2015; Bhargava and Choudhary 2004). Theoretical models in this literature are often industry-specific to incorporate the unique features of different industries. For example, Rochet and Tirole (2003) model the credit card market, Armstrong (2006) studies shopping malls and newspapers, and Zhu and Iansiti (2012) examine competition between video game consoles. We follow this tradition to build a model concerning competition between e-reader providers.

The extant theoretical models often focus on competition between symmetric platforms. The few papers examining competition between asymmetric platforms tend to examine platforms with very different business models. For example, Casadesus-Masanell and Ghemawat (2006) and Economides and Katsamakas (2006) examine the competition between proprietary and open source platforms, and Casadesus-Masanell and Zhu (2010) study the competition between a platform that is both subscription-based and ad-sponsored, and a platform that is entirely ad-sponsored. In contrast, our baseline model focuses on two platforms with similar business models; the only difference being the amount of value they create for users. We show that this difference alone leads to opportunities to cooperate while competing with each other.

A subset of the literature on two-sided markets addresses the issue of compatibility. Doganoglu and Wright (2006) examine the difference between multi-homing and compatibility, and find that multi-homing reduces platforms' incentives to achieve compatiblity. Orman (2008) finds that sometimes a proprietary platform may prefer compatibility when competing with an open and freely accessible platform. Miao (2009) shows that a monopoly platform has an incentive to remain incompatible in order to prevent competition in the complementary market. Casadesus-Masanell and Ruiz-Aliseda (2009) show that a large platform may prefer incompatibility because of the quest for market dominance. Viecens (2011) shows that a platform with a smaller stand-alone value will always prefer compatibility even though its competitor never will. Maruyama and Zennyo (2013) find that compatibility depends on product life cycles—when most users have purchased hardware, profits for platforms come largely from their content purchases. Dou (2014) finds, in a model with vertically differentiated platforms and content, that when inferior platform owns premium content, it is optimal for the inferior platform to offer such content to the superior platform. Typically, in these studies, providers of complementary applications or content are assumed to single-home. With compatibility users of one platform can therefore have access to applications or content on the other platform. In contrast, in our model, content providers multi-home (as they typically do in reality) and the benefit from compatibility comes from the access to the content reader that matches with users' preferences.

This work is also related to the studies on e-book pricing. For example, Hao and Fan (forthcoming) investigate how to price e-books and e-books reader under the wholesale and agency models. Different from these studies, we take the e-book pricing as given and focus on the compatibility decisions of two competing platforms.

The rest of the paper is organized as follows. Section 2 presents the setup of our baseline model. Section 3 provides equilibrium results under incompatibility and compatibility respectively. Section 4 compares the two cases and derives the conditions under which platforms prefer compatibility over incompatibility. We provide several extensions of our model in Section 6. While we build our model specific to the e-reader market, the basic insight that competing platforms with different focuses on their profit sources may have incentives to cooperate with each other applies to other platform-based markets as well. We discuss the generalizability of our results and conclude in Section 7.

2 Baseline Model

For ease of exposition, we use Apple's iPad and Amazon's Kindle as two competing platorms and use the standard Hotelling setup to model them as horizontally differentiated products. We use i to index iPad and k to index Kindle.

We assume that the two platforms, i and k, are located at locations 0 and 1 of a line of length 1, respectively. A continuum of consumers of measure 1 are uniformly distributed along the line, and each consumer chooses to adopt one of the two platforms. Consumer utility for each platform is the value she derives from the platform net the price and the disutility from the mismatch between the platform and her taste. The mismatch is measured by the distance between the platform's and her locations on the line. We denote p_j as price and U_j as the utility derived from platform j, $j \in \{i, k\}$. The utility for a consumer located at x from each device can be formulated as

$$U_i = v_i - tx - p_i \tag{1}$$

$$U_k = v_k - t(1-x) - p_k \tag{2}$$

in which v_j is the value derived from platform j, and t is the unit mismatch cost. Notice that v_j captures the value that a user derives from using the platform, such as reading e-books and using other platform features. As we discuss below, because book publishers multi-home, and platform providers use agency model, the utility from reading books is the same for both platforms. Because iPad provides many more additional features (e.g., map, flashlight and Internet browser) than Kindle, iPad offers an extra standalone utility and thus we assume $v_i > v_k$. We denote the difference in the standalone utilities as $v_d = v_i - v_k$, and assume that v_d is not too large such that in equilibrium both platforms have positive market shares. Because the hardware and software can be decoupled on each device, we assume that the unit mismatch cost, t, consists of both unit hardware mismatch cost, t_h, and software/reader mismatch cost, t_s: $t = t_h + t_s$. Consumers compare the two platforms and choose the one that offers greater utility.

When Kindle Reader is available on iPad, consumers who purchase iPad have the option between the two free software applications—iBooks and Kindle Reader, and choose the software that provides a lower mismatch cost. In particular, the software mismatch cost decreases for consumers who purchase iPad hardware but prefer Kindle Reader over iBooks. In this case, we can reformulate the utility that consumers derive from using iPad as

$$U_i = v_i - t_h x - t_s \min\{x, 1-x\} - p_i \tag{3}$$

As we will show below, in equilibrium, whether iBooks is available on Kindle device does not make a difference. For now, we assume that iBooks is unavailable on Kindle device, and the utility that consumers derive from using Kindle remains the same as in Equation (2).

We assume that book publishers multi-home and sell their e-books on both devices. Consistent with the current practices in the e-book market, we assume that the two platform providers both use an agency model, in which publishers set book prices and Amazon and Apple get a commission or royalty off each book sale occurred on their devices. We denote the commission that each device maker can earn from selling books to a consumer as γ. For ease of exposition, in this baseline model, we assume the marginal cost of the devices to be zero. We can then formulate the profit functions of Apple and Amazon from device buyers and book publishers as follows:

$$\pi_j = p_j D_{jh} + \gamma D_{js} \tag{4}$$

where $j \in \{i, k\}$, D_{jh} denotes the number of consumers who purchase hardware devices from platform j, and D_{js} is the number of consumers who use software by platform j to read e-books. When Kindle Reader is unavailable on iPad, the number of consumers who purchase hardware from a platform equals the number of consumers who use software offered by the same platform; that is $D_{jh} = D_{js}$. When Kindle Reader is available on iPad, some iPad buyers may use Kindle Reader instead of iBooks. In this case, $D_{ih} \geq D_{is}$ and $D_{kh} \leq D_{ks}$.

3 Equilibrium Analysis

We first analyze the incompatible case in which neither platform's software is available on its competitor's device, and then examine the one-way compatibility case in which Amazon's Kindle Reader is available on iPad.

3.1 Incompatible Case

When neither platform's software is available on its competitor's device, the competition between two platforms is similar to the standard Hotelling setup except that the two platforms offer different values v_i and v_k and the revenue for each firm comes from two sources—the hardware sales and commissions from e-book sales. As in the standard setup, by letting $U_i = U_k$, we can derive the indifferent consumer's location as $x^* = \frac{v_d-(p_i-p_k)+t}{2t}$. The consumers who have smaller mismatch to platform i than the indifferent consumer purchase platform i, and the other consumers purchase platform k. Hence, the profit functions of the two platforms in Equation (4) can be specified as

$$\pi_i = p_i x^* + \gamma x^* \tag{5}$$

$$\pi_k = p_k(1-x^*) + \gamma(1-x^*) \tag{6}$$

Solving the first order conditions for the two profit-maximizing platforms, we obtain the equilibrium prices, profits and indifferent consumer, as summarized by the following lemma.

Lemma 1. *When neither platform's software is available on its competitor's device, the equilibrium prices are*

$$p_i = \frac{1}{3}(3t + v_d - 3\gamma) \tag{7}$$

$$p_k = \frac{1}{3}(3t - v_d - 3\gamma) \tag{8}$$

the indifferent consumer is at $x^* = \frac{1}{2} + \frac{v_d}{6t}$*, and the equilibrium profits are*

$$\pi_i = \frac{(3t + v_d)^2}{18t} \tag{9}$$

$$\pi_k = \frac{(3t - v_d)^2}{18t} \tag{10}$$

Proof. All proofs are included in an appendix. □

Several observations of the equilibrium are worth highlighting. First, we notice that $p_i > p_k$, $x^* > \frac{1}{2}$, and $\pi_i > \pi_k$. This result is expected because iPad is more attractive to users than Kindle (captured by $v_i > v_k$ in the model), allowing Apple to charge a higher price as well as gain a larger market share. As a result, Apple makes more profits than Amazon.

Second, when the per-user e-book profit, γ, increases, both p_i and p_k decrease and can become negative (i.e., below cost). In such cases, the platforms have incentives to subside users for using the devices in return for profits from e-book sales. This pricing pattern and business model in general are similar to that for complementary products, such as the cases of selling printers and toner, or selling razors and blades.

Third, the equilibrium profits are unrelated to γ, although the prices depend on γ. This is because profits from e-book sales are competed away for the two platforms: as long as a platform can attract a user, it makes γ amount of additional profit. Platforms are therefore willing to subsidize each user up to γ amount in a competitive setting.

3.2 Compatible Case

To make the comparison easier, we use regular notation (e.g., p_j) in the incompatible case, and notation with a hat (e.g., $\hat{p}_j$) for outcome variables in the compatible case.

When Kindle Reader is available on iPad, the consumers who purchase iPad have the choice between two software applications and can choose the one that provides the better fit. If the indifferent consumer is located at $\hat{x}^* \geq \frac{1}{2}$, we can derive the indifferent consumer by letting $U_i = U_k$. In particular, based on Equations (2) and (3), we have

$$v_i - t_h\hat{x}^* - t_s(1 - \hat{x}^*) - \hat{p}_i = v_k - t_h(1 - \hat{x}^*) - t_s(1 - \hat{x}^*) - \hat{p}_k. \tag{11}$$

We thus have $\hat{x}^* = \frac{v_d-(\hat{p}_i-\hat{p}_k)+t_h}{2t_h}$. If the indifferent consumer is located at $\hat{x}^* < \frac{1}{2}$, because the consumers who purchase iPad prefer iBooks rather than Kindle Reader, the indifferent condition is the same as in the incompatible case and $\hat{x}^*$ takes the same form as x^*.

In this case, the consumers who have lower mismatch to product i than the indifferent consumer purchase platform i, and the other consumers purchase platform k. The demand for the hardware for platform i and k are $\hat{x}^*$ and $(1-\hat{x}^*)$, respectively. However, the demand for the software depends on the location of $\hat{x}^*$. When $\hat{x}^* < \frac{1}{2}$, the consumers who purchase iPad prefer iBooks and the demand for iBooks is $\hat{x}^*$. When $\hat{x}^* \geq \frac{1}{2}$, the consumers located at $\left[\frac{1}{2}, \hat{x}^*\right]$ purchase iPad but use Kindle Reader instead of iBooks. In other words, half of the users prefer iBooks and the other half prefer Kindle Reader. Notice that e-books sold through iBooks generate profits for Apple and those sold through Kindle Reader generate profits for Amazon. The profit functions of the two platforms in Equation (4) thus can be specified as

$$\hat{\pi}_i = \hat{p}_i\hat{x}^* + \gamma \min\left\{\frac{1}{2}, \hat{x}^*\right\} \tag{12}$$

$$\hat{\pi}_k = \hat{p}_k(1-\hat{x}^*) + \gamma(1-\hat{x}^*) + \gamma \max\left\{\hat{x}^* - \frac{1}{2}, 0\right\}. \tag{13}$$

Amazon's profits now come from Kindle hardware sales, and e-book sales through Kindle Reader on both Kindle and iPad. Solving the first order conditions for the two profit-maximizing platforms, we obtain the equilibrium prices, profits, and indifferent consumer, as summarized by the following lemma.

Lemma 2. *When Kindle Reader is available on iPad, the equilibrium prices are*

$$\hat{p}_i = \frac{1}{3}(3t_h + v_d) \tag{14}$$

$$\hat{p}_k = \frac{1}{3}(3t_h - v_d) \tag{15}$$

the indifferent consumer is at $\hat{x}^* = \frac{1}{2} + \frac{v_d}{6t_h}$, *and the equilibrium profits are*

$$\hat{\pi}_i = \frac{(3t_h + v_d)^2}{18t_h} + \frac{\gamma}{2} \tag{16}$$

$$\hat{\pi}_k = \frac{(3t_h - v_d)^2}{18t_h} + \frac{\gamma}{2} \tag{17}$$

In equilibrium, as in the incompatible case, $\hat{p}_i > \hat{p}_k$, $\hat{x}^* > \frac{1}{2}$, and $\hat{\pi}_i > \hat{\pi}_k$; in other words, Apple charges a higher price for its iPad than Amazon charges for its Kindle device, and Apple has a larger market share and earns higher profits than Amazon. As the indifferent consumer is located at $\hat{x}^* > \frac{1}{2}$, half of the consumers use Kindle Reader and the other half use iBooks, which explains the term $\frac{\gamma}{2}$ in the profit functions. As a result, revenue contribution from e-book sales is simply $\frac{\gamma}{2}$ for each platform. Because the number of consumers using iBooks or Kindle Reader is independent of hardware prices, Apple and Amazon's pricing decisions for their devices will only depend on the value their hardware provide to consumers. Since iPad offers a higher value than Kindle devices, Apple's iPad price is higher and its market share is greater in equilibrium. We also notice that, different from the incompatible case, although hardware prices are independent of the per-user e-book profit γ, the equilibrium profits are increasing with γ.

4 Comparison of the Two Cases

We next compare the equilibria in the two cases, and examine the condition under which both platforms have incentives to make Amazon's Kindle Reader available on Apple's iPad.

Comparing equilibrium prices in the two cases summarized in Lemmas 1 and 2, we have the following result.

Proposition 1. *If and only if $t_s \leq \gamma$, platforms charge higher prices in the compatible case than in the incompatible case (i.e., $p_j \leq \hat{p}_j$).*

The intuition is as follows. Recall that a platform's revenue consists of hardware sales and e-book sales. On the one hand, having Kindle Reader available on iPad reduces the competition for e-book sales, because it is always the case that the two platforms split the e-book demand evenly, while in the incompatible case, the two platforms compete for e-book demand, too. On the other hand, compared to the incompatible case, having Kindle Reader available on iPad increases the competition between the two platforms because of a reduction in platform differentiation and the extent of consumer preference— consumers located in $(1/2, \hat{x}^*)$ can now choose to use Kindle Reader, while in the incompatible case, they have no choice except using iBooks, which has a higher mismatch than Kindle Reader for them. The reduction in the competition for e-book sales is reflected by the per-user book profit γ. The increase in the competition due to the reduction in software differentiation is reflected by t_s. Whether platforms charge higher prices in the compatible case therefore depends on the balance between the reduction in the competition for e-book sales and the increase in the competition for hardware.

We also notice changes in the demand for each platform from the incompatible case to the compatible case.

Proposition 2. *More consumers purchase iPad in the compatible case than in the incompatible case:* $x^* < \hat{x}^*$.

As illustrated in Figure 1, with compatibility, Apple increases the sales of its iPad (from x^* to $\hat{x}^*$) but decreases its e-book sales via its iBooks (from x^* to 1/2). In contrast, Amazon expects decreases in the sales of its Kindle but increases in e-book sales. Therefore, each platform gains demand in one component—either hardware or software—but loses demand in the other. In some sense, being compatible works as a device of differentiation. Conventional wisdom tells us that being compatible may reduce the difference between the two platforms. However, in our case, making Kindle reader on iPad give users the option to use Kindle reader even if purchasing iPad. As a result, the software component is "unbundled" from the hardware component, and one platform dominates the hardware market and the other dominates the software market. The unbundling effect drives the differentiation outcome.

Having examined changes in prices and demands for each platform, we next compare equilibrium platform profits in these two cases to determine when both platforms have incentives to make Amazon's Kindle Reader available on Apple's iPad.

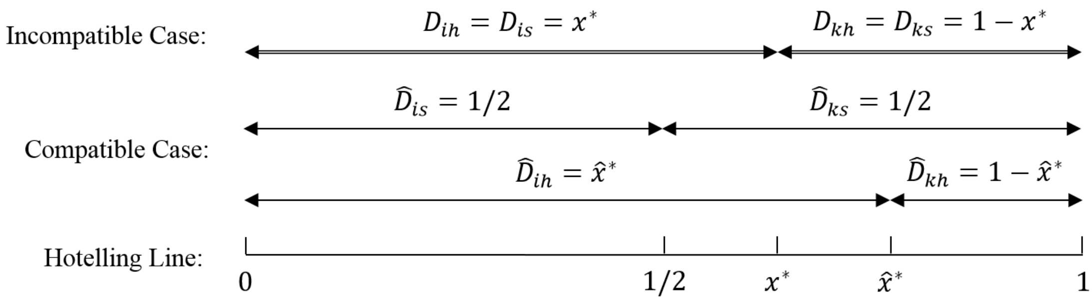

Figure 1: Changes in Demand for Each Firm

Proposition 3. *(a) If and only if* $9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$, *Apple and Amazon both have* *incentives to make Amazon's Kindle Reader available on Apple's iPad; (b) Both are more willing to make one-way compatibility when v_d is large and/or when γ is large.*

Apple is more willing to accept Kindle Reader when the device's value advantage (i.e., v_d) is larger. Having Kindle Reader available on iPad increases iPad revenues, even though it decreases e-book sales through iBooks. As v_d increases, Apple has more competitive advantage over the hardware and iPad sales become more important to Apple's profitability. Apple is then more willing to sacrifice e-book sales in return for greater iPad sales.

Interestingly, when the per-user book profit γ is larger, Apple is more likely to make Kindle Reader available on iPad. This result seems counter-intuitive, because, after all, e-book sales are a part of each platform's total revenue, and one would expect that as γ increases Apple should be less willing to let Amazon take its book business. This counter-intuitive result roots in the fundamental difference in the competition in the two cases. In the incompatible case, profits from e-book sales are competed away—platforms are willing to subsidize each user up to γ amount and the equilibrium profits are independent of γ. In contrast, in the compatible case, each platform earns $\frac{\gamma}{2}$ revenue from e-book sales and the revenue is increasing in per-user book sales γ. The different competition structures lead to the counter-intuitive result: when γ is larger, compared to the incompatible case, platforms charge relatively higher hardware prices and are more likely to achieve higher profits.

When v_d and/or γ are sufficiently large, both platforms have incentives to make Kindle Reader available on iPad. As a result, Apple relies more on its hardware sales and Amazon relies more on its book sales, and thus their major profit sources differ. Two special cases are worth highlighting. First, even when $v_d = 0$ such that the two platforms are symmetric, it is possible for the two platforms to be compatible if the per-user profit exceeds software differentiation. In this case, each platform receives a half of the demand both incompatible and compatible cases, but the price in the compatible case could be be higher because of the softened competition. Second, when value difference or per-user book profit γ is large such that Amazon is induced to subside users for using the devices in return for profits from e-book sales, both platforms always have incentive to be compatible because these scenarios give firms profitable opportunities to differentiate from each other and exploit consumers in one dimension each.

We next examine the effect of compatibility on social welfare. Social welfare here is defined as the sum of consumers' utilities and platforms' profits, which equals the total consumer value realized from the consumption of the products. Therefore, in the incompatible case, the total social welfare generated can be formulated as

$$W(x^*) = \int_0^{x^*} (v_i - t_h x - t_s x)dx + \int_{x^*}^1 [v_k - t(1-x)]\,dx \tag{18}$$

and in the compatible case, the total social welfare generated can be formulated as

$$\hat{W}(\hat{x}^*) = \int_0^{\hat{x}^*} (v_i - t_h x - t_s \min\{x, 1-x\})dx + \int_{\hat{x}^*}^1 [v_k - t(1-x)]\,dx \tag{19}$$

The main difference between the formulations of social welfare under the two cases is the mismatch cost associated with software applications. It is easy to see that if the locations of the indifferent consumers were the same (i.e., $x^* = \hat{x}^*$), social welfare in the compatible case would be always higher than that under the incompatible case. This is because the software mismatch cost for consumers at $[0, \hat{x}^*]$ in the compatible case is $t_s \min\{x, 1-x\}$ and in the incompatible case is $t_s x$. The former is always smaller than the latter. As illustrated in Figure 1, the indifferent consumer's location in the compatible case is to the right of that in the incompatible case. We can show that moving the indifferent consumer to the right pushes the social welfare toward a more efficient allocation.

Proposition 4. *The compatible case generates greater social welfare than the incompatible case.*

The efficiency gain in the compatible case comes from two parts. First, being compatible results in a better allocation of hardware because more consumers buy iPad, which pushes toward an efficient allocation. Second, being compatible also leads to a better allocation of book buyers because iPad users now have the choice of using Kindle reader.

5 Apple's iBooks on Kindle?

We next examine whether Apple has incentives to make iBooks available on Amazon's Kindle device. There are two possible scenarios depending on whether Amazon's Kindle Reader is already available on Apple's iPad. Examining each scenario, we have the following result:

Proposition 5. *Regardless of whether Amazon's Kindle Reader available is on Apple's iPad, Apple is indifferent between having its iBooks on Kindle or not.*

The intuition is that in both scenarios, less than 50% of the consumers will buy Kindle. All these consumers will choose Kindle Reader regardless of whether iBooks is available to them or not because their mismatch cost with Kindle Reader is smaller. Having iBooks available on Kindle devices therefore makes no difference in the end.

6 Extensions

In this section, we extend the baseline model by examining factors such as different production costs, exclusive titles, endogenized royalty rates and wholesale vs. agency models used by the platforms affect the platforms' compatibility incentives.

6.1 Different Production Costs

In the baseline model, we assume that the two platforms have identical production costs and normalize their costs to be zero. In this extension, we allow the platforms to have different costs. In particular, we consider that Apple has a higher production cost for its iPad than Amazon for its Kindle. This assumption is more sensible than the other way, because we assume that iPad provides a higher standalone utilit to consumers than a Kindle (i.e., $v_d > 0$) and typically a higher value product comes with a higher production cost. As in the baseline model, we normalize the production cost for Kindle to be zero and assume that the production cost for an iPad is c, $c \geq 0$.

The main difference from the baseline case is that the profit function for Apple in the incompatible case in Equation (5) now becomes

$$\pi_i = (p_i - c)\, x^* + \gamma x^*,$$

and the profit function in the compatible case becomes

$$\hat{\pi}_i = (\hat{p}_i - c)\hat{x}^* + \gamma \min\left\{\frac{1}{2}, \hat{x}^*\right\}.$$

Proposition 6. *(a) If and only if $v_d \geq c$ and $9(\gamma - t_s) + (v_d - c)^2(\frac{1}{t_h} - \frac{1}{t}) \geq 0$, Apple and Amazon have incentive to have Amazon's Kindle Reader on Apple's iPad; (b) Both platform providers are more willing to have this one-way compatibility when $(v_d - c)$ is large and/or when γ is large.*

Different from the baseline model, instead of the value advantage v_d, the difference $(v_d - c)$ affects platforms' incentive to be compatible. We also notice that it becomes more difficult for the two platforms to be compatible, compared with the baseline case. The intuition here is that with production cost, it is more difficult for Apple to generate a huge profit from hardware sales. As a result, Apple's profit from selling books becomes more important. The profit focuses of the two platform providers become more similar to each other as a result of production cost, thus reducing the incentives to be compatible.

6.2 Exclusive E-Book Titles on Amazon

In the baseline model, we assume that all book publishers multi-home and all e-books are available on both platforms. In practice, Amazon, established as the primary book retailer online, may have bargaining power over some book publishers and thus can request for exclusive deals with Amazon. Also, some book publishers may choose to simply sell their e-books on one platform only, considering the cost of setting up and contracting with platforms.[1] In this extension, we consider the case in which Amazon has some exclusive e-book titles and examine platforms' compatibility incentives.

We consider the value v_j that consumers derive from platform j can be decomposed into two components: the value derived from reading e-books ($v_j b$) and the value of using other functions (v_{jo}). In the baseline model, because book publishers are multi-homing, consumer utilities from book consumption on both platforms are identical; that is, $v_j b$ is the same for both platforms, which is denoted as v_b. Therefore, we can view $v_k = v_b + v_{ko}$ and $v_i = v_b + v_{io}$, where $v_{io} - v_{ko} = v_d$. As value derived from reading e-books does not affect consumers' preference of the two platforms, we have not explicitly expressed these utilities in our utility functions. In this extension, the number of exclusive titles on Amazon affects consumer preferences between the two platforms. We thus explicitly account for utilities from reading books.

[1] Our conversations with Amazon and Apple in March 2014 indicate that while both Amazon's Kindle Store and Apple's iBooks store have over 2 million e-books, Amazon has over 500,000 exclusive titles that readers could not find anywhere else.

We normalize the number of the e-books that are available on both platforms to be 1. In addition, Amazon has k exclusive titles. The number of exclusive titles on Amazon directly affects consumers utility derived from Amazon's Kindle device as well as Amazon's profit. When Amazon has k exclusive titles, consumer utility from iPad remain the same as in the baseline model $U_i = v_{io} + v_b - tx - p_i$. Different from the baseline model, the utility that consumers derive from Kindle becomes $U_k = v_{ko} + (1+k)v_b - t(1-x) - p_k$ because of the increased number of book titles. Basically, we assume that with more exclusive titles Kindle appears more attractive to consumers. We redefine the value difference $\bar{v}_d = (v_{io} + v_b) - [v_{ko} + (1+k)v_b] = v_d - kv_b$. Because of the exclusive titles on Amazon, the value of Kindle is enhanced and the value difference is smaller than that in the baseline case.

The value v_b can be interpreted in a more specific way. We assume that each book publisher offers one e-book. Each consumer derives a utility $\tilde{v}$ for a given book and $\tilde{v}$ is randomly drawn from a uniform distribution $[0, \bar{v}_b]$. Each book publisher is a monopoly for the e-book it publishes and charges a price of p_b for the e-book. Consumers purchase all e-books from which they derive non-negative utilities: $\tilde{v} - p_b \geq 0$. Given the setup, the optimal monopoly price book publishers set is $p_b^* = \bar{v}_b/2$, and each consumer purchases half of the e-books available on the platform. Hence, each consumer derives a total utility of $\int_{p_b^*}^{\bar{v}_b}(\tilde{v} - p_b^*)d\tilde{v} = \bar{v}_b^2/8$ from books on iPad and $(1+k)\bar{v}_b^2/8$. Therefore, under this setting, $v_b = \bar{v}_b^2/8$.

We can similarly compare the incompatible and compatible cases. The main difference is that the number of exclusive e-books on Amazon plays a role in the comparison. The condition under which both platforms have incentive to have Amazon's Kindle Reader on Apple's iPad is as follows.

Proposition 7. *(a) When* $9(\gamma - t_s) + \bar{v}_d^2(\frac{1}{t_h} - \frac{1}{t}) + k\gamma\frac{6t+2\bar{v}_d-k\gamma}{t} \geq 0$*, Apple has incentives to have Amazon's Kindle Reader on Apple's iPad. (b) When* $9(\gamma - t_s) + \bar{v}_d^2(\frac{1}{t_h} - \frac{1}{t}) + k\gamma\frac{3t+2\bar{v}_d-k\gamma}{t} \geq 0$*, Amazon has incentives to have Amazon's Kindle Reader on Apple's iPad.*

Notice that when k is zero, the above conditions reduce to the one in Proposition 3. When k is positive, interestingly, now the two platform providers' incentives to have Amazon's Kindle Reader on iPad are not always aligned: Apple generally has greater incentives to be compatible than Amazon. The reason is that compatibility allows iPad users now to access these exclusive e-books in addition to Kindle Reader, and hence it now provides more value to iPad users.

However, compared to the baseline case, it is unclear whether the two platform providers are now more willing to have the one-way compatibility. On one hand, exclusive titles increase Amazon's reliance on content sales. As a result, they increase the heterogeneity in two platforms' profit focuses and thus increase the likelihood of compatibility. On the other, these exclusive titles increase the value of Amazon to its users, thus reducing difference in the utilities users receive from both platforms ($\bar{v}_d < v_d$). This reduction in heterogeneity reduces the likelihood of compatibility. In the end, whether exclusive titles increase the likelihood on compatibility depends on the relative impact on utility difference and extra profits from additional content sales to the platform. For example, when γ is large, the exclusive content generates great profits to Amazon through book sales, the former effect is likely to dominate and hence exclusive content will increase the willingness to be compatible.

6.3 Endogenized Royalty Rate

In our baseline model, the per-user book profit, γ, is assumed to be the same for both platforms. While this assumption matches with the e-reader market, where the two platforms charge similar prices for e-books and the same royalty rate, to make our model more generalizable to other settings, we extend the model to endogenize royalty rate. The royalty rate is typically determined through negotiations between a platform and book publishers. The bargaining power of a platform is likely to depend on its market share in the hardware market. Hence, we assume the royalty rate to be a constant, $b \in [0, 1]$, multiplied by the equilibrium market share of the platform. The parameter, b, reflects the importance of market share on the negotiation outcome. Using the notations described in Section 6.2, for Apple, $r_i = bx^*$, and for Amazon, $r_k = b(1 - x^*)$.

We assume that an average user pays g for e-books such that γ be be viewed as $\gamma = r_i g$. Thus, in the incompatible case, while the consumers' utility functions remain the same, the profit functions of the two platforms become:

$$\begin{aligned} \pi_i &= p_i x^* + bgx^{*2} \\ \pi_k &= p_k(1 - x^*) + bg(1 - x^*)^2. \end{aligned}$$

To avoid corner solutions, we assume that $bg < t$. Solving the first order conditions, we find that the indifference consumer is located at $x^* > 1/2$ and obtain the equilibrium profits as:

$$\begin{aligned}\pi_i &= \frac{(2t - bg)(v_d + 3t - bg)^2}{4(3t - bg)^2} \\ \pi_k &= \frac{(2t - bg)(v_d - 3t + bg)^2}{4(3t - bg)^2}\end{aligned}$$

With compatibility, the profit functions become:

$$\begin{aligned}\hat{\pi}_i &= \hat{p}_i \hat{x}^* + bg \left(\min \left\{ \frac{1}{2}, \hat{x}^* \right\} \right)^2 \\ \hat{\pi}_k &= \hat{p}_k (1 - \hat{x}^*) + bg \, (1 - \hat{x}^*)^2 + bg \left(\max \left\{ \hat{x}^* - \frac{1}{2}, 0 \right\} \right)^2\end{aligned}$$

We similarly derive the equilibrium profits as:

$$\begin{aligned}\hat{\pi}_i &= \frac{bg}{4} + \frac{(v_d + 3t_h)^2}{18 t_h} \\ \hat{\pi}_k &= \frac{bg}{4} + \frac{(v_d - 3t_h)^2}{18 t_h}\end{aligned}$$

Comparing equilibrium profits in both cases, we derive the following proposition:

Proposition 8. *There exists a threshold, v_d^*, such that when $v_d < v_d^*$, as b increases, both platforms are more likely to be compatible; when $v_d \geq v_d^*$, as b increases, both platforms are less likely to be compatible.*

The intuition is that when v_d is small, under the incompatible case, because of lack of differentiation, the two platforms have similar profit focuses. As b increases, the profits from selling books become more important. Hence, the two platforms compete more aggressively in attracting users to adopt their hardware. This intense competition for users hurt profitability for both platforms. Compatibility softens this competition. As a result, as b increases, both platforms are more willing to be compatible. When v_d is large, under the incompatible case, there is already a strong incentive to be compatible because of their different profit focuses. As b increases, both platforms find the profits from selling books become more important. As a result, a greater b reduces the difference in the profit focuses of the two platforms. As their profit focuses become more similar to each other, they are less likely to be compatible.

6.4 Wholesale vs. Agency Pricing

Our baseline model assumes that both platforms use the agency model with book publishers, in which content owners set content prices and pay commission to the platforms. In practice, while Apple has always used the agency model, Amazon had used the wholesale model, where it bought e-books from book publishers and resold them, before it switched to the agency model. In this extension, we investigate the case where the two platforms to use different models—Amazon use wholesale model to sell e-books and Apple use the agency model—and compare their compatibility incentives to the baseline case.

To make clear comparison, we assume that an average user pays g for e-books if she chooses iPad platform. We continue to normalize the number of the e-books that are available on both platforms to be 1. Under wholesale pricing scheme, Amaze may charge a different price. We denote as d_k the discount that Amazon offers for its ebook. When $d_k < 0$, Amazon charges higher prices than Apple for its books. For the incompatible case, we formulate users' utility functions as follows.

$$U_i = v_i - tx - p_i - g \tag{20}$$

$$U_k = v_k - t(1-x) - p_k - (1-d_k)g \tag{21}$$

Similar to the baseline case, we can derive the indifferent consumer's location as $x^* = \frac{v_d - (p_i - p_k) + t - d_k g}{2t}$. Under the agency pricing scheme, as in Section 6.3, we assume the royalty rate depends on the bargaining power of the platform, which in turn depends on its market share. For Apple, $r_i = bx^*$, and thus its profit is $\pi_i = p_i x^* + r_i g x^*$. Under the wholesale pricing scheme, the wholesale price should also depends on Amazon's bargaining power. Given the average price a consumer pay for e-books g, we assume that the final wholesale price to be $(1-r_k)g$, in which r_k, modeled in the same fashion as r_i, depends on Amazon's market share; that is, $r_k = b(1-x^*)$. If Amazon does not give consumers discount for its e-books (i.e., $d_k = 0$), r_k is equivalent to the loyalty rate under the agency pricing scheme, and the wholesale pricing scheme in this case is equivalent to the agency pricing scheme. In general, Amazon's profits can be formulates as: $\pi_k = p_k(1-x^*) + (r_k - d_k)g(1-x^*)$.

Solving the first order conditions for the two profit-maximizing firms, we can obtain the equilibrium outcome. In particular, we find that equilibrium pricing for Amazon requires $(p_k - d_k g)$ to be a certain value, but we cannot separate identify p_k and d_k. The reason is that in the incompatible case, offering a discount to e-books is essentially equivalent to offering a discount to the device. The price difference between $(p_k - d_k g)$ and p_i, not the discount rate, affects consumers' purchase decisions. Technically, we can rewrite Amazon's profit function as $\pi_k = (p_k - d_k g)(1-x^*) + r_k g(1-x^*)$, which indicates that it is the overall price $(p_k - d_k g)$, not the discount rate alone, determines the profits. Notice that for Amazon, the case with $d_k = 0$ under the wholesale pricing scheme is equivalent to the agency pricing scheme. Therefore, in the incompatible case, the wholesale pricing and agency pricing schemes lead to the same equilibrium outcome.

We next examine the compatible case in which Amazon's Kindle Reader is available on iPad. In this case, consumers who purchase iPad can choose iBook or Kindle Reader to read e-books and thus their utility function become as follows:

$$U_i = v_i - t_h \hat{x} - \hat{p}_i - \min\left\{t_s x + g, t_s(1-x) + (1-\hat{d}_k)g\right\} \tag{22}$$

As in the baseline case, we consider the case with the indifferent consumer $\hat{x}^* > \frac{1}{2}$ in equilibrium, and we can derive $\hat{x}^* = \frac{v_d - (\hat{p}_i - \hat{p}_k) + t_h}{2t_h}$. Among the users who purchase iPad, the indifferent e-book user is determined by

$$t_s \hat{x}_b^* + g = t_s(1 - \hat{x}_b^*) + (1 - \hat{d}_k)g \tag{23}$$

We can derive the indifferent book user $\hat{x}_b^* = \frac{t_s - \hat{d}_k g}{2t_s}$. Based on the two indifferent points, we can formulate Apple's profits as $\hat{\pi}_i = \hat{p}_i \hat{x}^* + r_i g \hat{x}_b^*$, where $r_i = b\hat{x}_b^*$, and Amazon's profits as $\hat{\pi}_k = \hat{p}_k(1-\hat{x}^*) + (r_k - \hat{d}_k)g(1-\hat{x}_b^*)$, where $r_k = b(1-\hat{x}_b^*)$.

Solving the first order conditions for the two profit-maximizing firms, we can obtain the equilibrium outcome. In particular, the equilibrium profits of the two platforms are the function of the discount rate $\hat{d}_k$ offered by Amazon:

$$\begin{aligned}
\hat{\pi}_i &= \frac{bg(t_s - \hat{d}_k g)^2}{4t_s^2} + \frac{(v_d + 3t_h)^2}{18t_h} \\
\hat{\pi}_k &= \frac{bg(t_s + \hat{d}_k g)^2 - 2\hat{d}_k t_s(t_s + \hat{d}_k g)}{4t_s^2} + \frac{(v_d - 3t_h)^2}{18t_h}
\end{aligned}$$

We can verify that the $\hat{\pi}_i$ decreases in $\hat{d}_k$ and $\hat{\pi}_k$ increases in $\hat{d}_k$. As in the incompatible case, the case with $\hat{d}_k = 0$ under the wholesale pricing scheme is equivalent to the agency pricing. In this compatible case, we can derive equilibrium $\hat{d}_k^* = \frac{t_s(bg-t_s)}{g(2t_s-bg)}$, which is positive. Therefore, we can conclude the following comparison.

Proposition 9. *Compared to the agency pricing scheme, when Amazon uses wholesale pricing scheme, Amazon has greater incentive and Apple has less incentive to be compatible.*

As in the baseline case, being compatible can differentiate the two platforms by letting one dominating software market and the other dominating the hardware market. In the compatible case, compared to the agency model in which both firms charge the same price for e-books, under the wholesale pricing scheme Amazon can directly set the e-books retail prices to its advantage and thus Apple has some disadvantage. In the incompatible case, software is bundled with hardware. Therefore, even though it can directly set its e-books prices, Amazon cannot benefit from this direct price control in this software dimension because consumers at the end care about the price of the bundle.

7 Conclusions

In this paper, we show that two platforms have incentives to achieve one-way compatibility when the difference in their values to consumers is sufficiently large or the royalty from content sales is large. While we build our model specific to the e-reader market, the general insight is also applicable to other industries. For example, Microsoft's Surface competes with Apple's iPad in the tablet market. One important differentiation between the two tablets is that Surface comes with Microsoft software applications such as Microsoft Office, while iPad comes with many software applications developed by Apple such as Keynote. On March 27, 2014, Microsoft made its Office software available for iPad so that iPad users can now purchase it. Similar to the iPad versus Kindle case, Microsoft's decision to achieve one-way compatibility is likely to decrease the Surface's market in the tablet market. On the other hand, Microsoft will be able to gain additional profit from software sales to iPad users. Because iPad is much more attractive than Surface, consistent with our theoretical prediction, both Microsoft and Apple have incentives to make Microsoft Office available on iPad.[2]

Two-sided platforms are often characterized by incompatibility. Casadesus-Masanell and Ruiz-Aliseda (2009) show that the incentive to dominate the market prevents platforms from becoming compatible. In contrast, our study shows that another reason we do not observe greater compatibility might be that competing platforms are too similar to each other and provide similar value to users. For example, in the video game industry, Microsoft's Xbox and Sony's PlayStation offer a similar set of features to users, and they closely match each other's pricing strategies. As a result, neither Microsoft nor Sony has incentive to encourage game compatibility.

One limitation of our paper is that we assume that the per-user e-book profit for both platforms are the same. While this matches with platform practices in the e-reader market, it is possible that in other markets, platforms may generate different amounts of per-user profit.

The second limitation is that we only study the cases in which compatibility requires both platforms to agree. It is possible that in some contexts, compatibility can be achieved by means of an adapter. It will be interesting in future research to study how such possibilities affect platforms' pricing and compatibility decisions.

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[2]In November 2014, Microsoft made the basic version of Office app on iPad for free and users only needed pay for premium features.

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Appendix

Proof of Proposition 1. Because $p_i = \frac{1}{3}(3t + v_d - 3\gamma) = \frac{1}{3}(3t_h + v_d + 3t_s - 3\gamma)$ and $\hat{p}_i = \frac{1}{3}(3t_h + v_d)$, $p_i \leq \hat{p}_i$ if and only if $t_s \leq \gamma$. The same reason applies to platform k. □

Proof of Proposition 2. Notice that $x_b^* = \frac{1}{2} + \frac{v_d}{6t}$ and $x^* = \frac{1}{2} + \frac{v_d}{6t_h}$ by Lemmas 1 and 2. Because $t_h < t$, $x_b^* < x^*$. □

Proof of Proposition 3. (a) Notice that $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{v_d^2}{18t_h} + \frac{\gamma}{2} \geq \frac{t}{2} + \frac{v_d^2}{18t}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition.

(b) Notice $\hat{\pi}_i - \pi_i = \frac{1}{18}\left[9(\gamma - t_s) + v_d^2(\frac{1}{t_h} - \frac{1}{t})\right]$, which increasing in v_d and γ. □

Proof of Proposition 4. We can verify that $\hat{W}(\hat{x}^*)$ in Equation (19) is concave in $\hat{x}^*$. Also, we can verify that the socially efficient indifferent point, $\hat{x}_{sc}^*$, cannot be in $[0, 1/2]$. We thus derive the efficient indifferent point considering $\hat{x}_{sc}^* \in [1/2, 1]$. By the first order condition of Equation (19), the efficient indifferent point must satisfy

$$v_i - t_h\hat{x}_{sc}^* - t_s(1 - \hat{x}_{sc}^*) - [v_k - t(1 - \hat{x}_{sc}^*)] = 0$$

Noticing that $t = t_h + t_s$, we have efficient indifferent point $\hat{x}_{sc}^* = \frac{1}{2} + \frac{v_d}{2t_h}$. Notice $\hat{x}^* = \frac{1}{2} + \frac{v_d}{6t_h} < \hat{x}_{sc}^*$. By Proposition 2, $x^* < \hat{x}^*$. We thus have $\frac{1}{2} < x^* < \hat{x}^* < \hat{x}_{sc}^*$, and by the concavity, we have $W(x^*) < \hat{W}(\hat{x}^*)$. Meanwhile, as explained above and it is easy to verify, $W(x^*) < \hat{W}(x^*)$. Therefore, we have $W(x^*) < \hat{W}(\hat{x}^*)$. □

Proof of Proposition 5. The proof is straightforward by noting that all users of Kindle device will prefer Kindle app to iBooks. As a result, no users of Kindle device will use iBooks even if Apple makes iBooks available on Kindle. □

Proof of Proposition 6. Solving the first order condition for the two profit-maximizing platforms, we can similarly derive equilibrium prices, demand and profits. For example, in the incompatible case, the equilibrium prices are

$$p_i = \frac{1}{3}(2c + 3t + v_d - 3\gamma) \quad (24)$$

$$p_k = \frac{1}{3}(c + 3t - v_d - 3\gamma) \quad (25)$$

the indifferent consumer is located at $x^* = \frac{1}{2} + \frac{v_d - c}{6t}$, and the equilibrium profits are

$$\pi_i = \frac{(3t + v_d - c)^2}{18t} \tag{26}$$

$$\pi_k = \frac{(3t - v_d + c)^2}{18t} \tag{27}$$

Obviously, Apple's cost disadvantage affects its equilibrium price, demand, and profit. For instance, compared to the baseline case with equal cost, the cost disadvantage induces Apple to charge a higher price and results in a lower demand. In particular, in the baseline case, Apple's demand is always greater than $\frac{1}{2}$ (i.e., $x^* > 1$ by Lemma 1). In contrast, when Apple has a cost disadvantage, its demand now is lower and can be even below $\frac{1}{2}$ when the value advantage cannot compensate the additional cost (i.e., when $v_d < c$).

In the compatible case, we obtain the equilibrium prices as:

$$\hat{p}_i = \frac{1}{3}(2c + 3t_h + v_d) \tag{28}$$

$$\hat{p}_k = \frac{1}{3}(c + 3t_h - v_d) \tag{29}$$

The indifferent consumer is located at $\hat{x}^* = \frac{1}{2} + \frac{v_d - c}{6t_h}$.

Similar to the baseline model, we can derive the equilibrium profit for the compatible case as

$$\hat{\pi}_i = \frac{(3t_h + v_d - c)^2}{18t_h} + \frac{\gamma}{2} \tag{30}$$

$$\hat{\pi}_k = \frac{(3t_h - v_d + c)^2}{18t_h} + \frac{\gamma}{2} \tag{31}$$

Therefore, $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{(v_d - c)^2}{18t_h} + \frac{\gamma}{2} - \frac{t}{2} + \frac{(v_d - c)^2}{18t} \geq 0$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition. The condition for platform k can be similarly derived. □

Proof of Proposition 7. Based on this utility function, as in the baseline model, we can similarly derive the indifferent consumer's location for each case, and formulate each platform's demand and profit function. Then, again, based on the best response to each other, we can derive the equilibrium prices, indifferent consumer's location, and equilibrium profits for both the incompatible and compatible cases. For example, in the incompatible case, based on this newly defined v_d, the expression for the indifferent point x^* is the same as in the baseline model. Apple's profit function also remains the same as in Equation (5). Amazon's profit in Equation (6) now becomes

$$\pi_k = p_k(1 - x^*) + (1 + k)\gamma(1 - x^*)$$

which indicates that Amazon has additional $k\gamma$ per-user book sales because its exclusive book titles, compared to Apple's per-user book sales. Solving the first order condition for the two firms' profit maximizing problems, we can obtain the equilibrium prices as

$$p_i = \frac{1}{3}\left[3t + \bar{v}_d - (3+k)\gamma\right] \tag{32}$$

$$p_k = \frac{1}{3}\left[3t - \bar{v}_d - (3+2k)\gamma\right] \tag{33}$$

The indifferent consumer is at $x^* = \frac{1}{2} + \frac{v_d - k\gamma}{6t}$, and the equilibrium profits are

$$\pi_i = \frac{(3t + \bar{v}_d - k\gamma)^2}{18t} \tag{34}$$

$$\pi_k = \frac{(3t - \bar{v}_d + k\gamma)^2}{18t} \tag{35}$$

Notice now the even if the value difference is positive (i.e., $\bar{v}_d > 0$), the indifferent point can be less than $\frac{1}{2}$ such that Kindle has more equilibrium demand than iPad. The reason is that now Amazon has exclusive titles, one additional user means more e-book sales for Amazon than for Apple. As a result, Amazon prices more aggressively to compete for consumers.

For the compatible case, similarly, based on this newly defined $\bar{v}_d$, Apple's profit function takes the same form as in the baseline model, and Amazon's profit function is adjusted by k as follow:

$$\hat{\pi}_k = \hat{p}_k(1 - \hat{x}^*) + (1+\gamma)(1 - \hat{x}^*) + (1+\gamma)\max\left\{\hat{x}^* - \frac{1}{2}, 0\right\}$$

We consider the scenario in which the equilibrium indifferent consumer is located at $\hat{x}^* > \frac{1}{2}$, because otherwise whether the platform is compatible makes little difference. Solving the first order condition for the two platforms' profit maximizing problems, we find that the prices, indifferent consumer's location, and Apple's profit take the same form as in the baseline model. Amazon's profit function becomes

$$\hat{\pi}_k = \frac{(3t_h - \bar{v}_d)^2}{18t_h} + \frac{(1+k)\gamma}{2}$$

because of the exclusive titles.

(a) Recall $\hat{\pi}_i = \frac{(3t_h + \bar{v}_d)^2}{18t_h} + \frac{\gamma}{2}$. $\hat{\pi}_i \geq \pi_i$ requires

$$\frac{t_h}{2} + \frac{\bar{v}_d^2}{18t_h} + \frac{\gamma}{2} \geq \frac{t}{2} + \frac{(\bar{v}_d - k\gamma)^2}{18t} - \frac{k\gamma}{3}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition.

(b) Notice that $\hat{\pi}_k \geq \pi_k$ requires

$$\frac{t_h}{2} + \frac{\bar{v}_d^2}{18t_h} + \frac{(1+k)\gamma}{2} \geq \frac{t}{2} + \frac{(\bar{v}_d - k\gamma)^2}{18t} + \frac{k\gamma}{3}$$

Noticing $t = t_h + t_s$, this condition can be simplified to the one in the proposition. □

Proof of Proposition 8. First notice that $\hat{\pi}_i - \pi_i > \hat{\pi}_k - \pi_k$. Hence, the gain for Apple from compatibility is smaller than the gain for Amazon. As a result, if Apple prefers compatibility to incompatibility (i.e., $\hat{\pi}_i - \pi_i > 0$), Amazon will prefer compatibility, too. So we only need to examine Apple's profit change. Differentiating $\hat{\pi}_i - \pi_i$ with respect to b, we have

$$\frac{d(\hat{\pi}_i - \pi_i)}{db} = 9\left(2 + \frac{v_d(t(6t+5U_d) - 2b(2t+v_d))}{(3t-2b)^2}\right).$$

We find that $\frac{d(\hat{\pi}_i - \pi_i)}{db} > 0$ when $v_d < v_d^*$ and $\frac{d(\hat{\pi}_i - \pi_i)}{db} \leq 0$ when $v_d \geq v_d^*$, where $v_d^* = \frac{(3t-2b)(-t+\sqrt{8(2t-b)^2-t^2})}{(5t-2b)}$. $\square$